wind had flowed over the northerly and had its moisture precipitated by it. Still, it seems probable that a part of the southerly wind did continue on its course and produce the snow which was observed to fall. I infer that the current was mainly turned back upon itself so that the moisture as fast as precipitated fell through the lower current still blowing from the southeast. My idea may best be illustrated by a diagram (p. 159).

The diagram anticipates with remarkable exactness the form of a cold current underrunning still, warm air, found experimentally by W. Schmidt (4).

A tornado in northeastern Ohio in February, 1842, started Loomis studying two storms of that month. His paper on these storms (5) created a great sensation at the centennial meeting of the American Philosophical Society in May, 1843, both on account of the light that it shed on the theories of Redfield and Espy, and still more by reason of his invention of the synoptic weather map with isobars and isotherms. He had no means of reducing the barometer to sea level so that he was obliged to draw isobars of equal departure from normal. His paper is illustrated with 13 of these maps, 7 showing the progress of the parent storm of the tornado from February 2 to 5, 1842, the other 6 show the storm of February 15–17, 1842, both at 12-hour intervals. Brandes at Leipzig had constructed similar maps in 1820 and 1826, but did not publish them. Loomis was apparently unaware of the work of Brandes, and is in any case entitled to the credit of first publication.

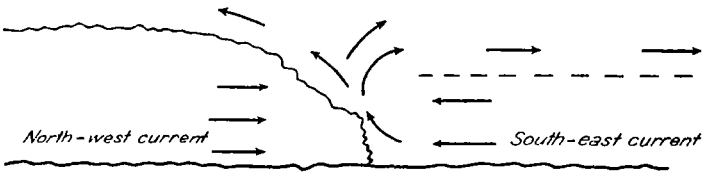
In this paper again, Loomis is concerned with the thermodynamics of ascending and descending air, and quotes the observations and experiments of Poisson, Gay-Lussac, Forbes, Pouillet, Leslie, and especially the experiment of Clement and Desormes which is still repeated by sophomores in the college course in physics to-day. The following quotation (p. 174) shows one of Loomis's applications of the theory:

> As the westerly wind pours over the (Allegheny) mountains and descends to the level of the sea it comes under greater pressure, and heat is developed which dissolves the vapor, producing clear sky. Thus clear sky succeeds a storm much sooner on the eastern than on the western side of the mountains.

This paper also contains two anticipations of the Bjerknes Polar Front theory (p. 178). "These oscillations are propagated by the laws of waves." On page 180 he charts the instantaneous directions of the winds in two cyclones and shows that these consist of two streams of air, of which the northwest current revolves in an inflowing spiral around and impinges against the side of the southeast current.

Loomis numbered among his students at Western Reserve College an energetic fellow, Halbert E. Paine, who rose to be major general of Volunteers in the Civil War, was elected to Congress while yet in camp, and afterward was appointed Commissioner of Patents. In the second of these capacities Paine put through Congress in the record time of seven days the act that started our present national weather service.

Loomis went to the University of New York in 1844, where he wrote many of the textbooks that made him famous and wealthy. He succeeded Joseph Henry at Princeton when the latter became the first secretary of the Smithsonian Institution, but Loomis was induced to return to New York the following year and remained



until 1860 when his alma mater, Yale, called him to the professorship that he held the remainder of his life. His Treatise on Meteorology was published in 1868. Beginning 1874 he presented a series of 23 contributions to meteorology to the National Academy of Sciences.

Loomis's prestige was used by Henry to support the extensive meteorological program of the Smithsonian Institution when it was organized in 1847, and by Paine again in 1870 when the meteorological work was initiated under the chief signal officer of the Army, which has developed into the present United States Weather Bureau.

Loomis passed away in 1889 at the age of 78. His fortune of $300,000 derived from his text-books, left to Yale University, was the largest bequest received up to that time by that institution.

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(3) Loomis, E. On the storm which was experienced throughout the United States about the 20th of December, 1836. Trans. Am. Phil. Soc. n. s. vol. 7, 1841.

(4) Schmidt, W. Zur Mechanik der Boen, Met. Zeit, vol. 28, 1911, p. 355–362.

(5) Loomis, E. On two storms which were experienced throughout the United States in the month of February, 1842. Trans. Am. Phil. Soc. n. s. vol. 9, 1846.

GREAT DUST STORM IN WASHINGTON AND OREGON, APRIL 21–24, 1931 [1]

By DONALD C. CAMERON

[Weather Bureau Airport, Portland, Oreg.]

SYNOPSIS

A considerable part of Washington and Oregon experienced on April 21–24, 1931, an extraordinary dust storm borne on strong northeast winds that were common to both States, although of greater force in some parts than in others.

A week previous saw the end of a rather protracted wet spell in both States which was succeeded by clear skies very low relative humidity under which the top layers of the soil had dried out very thoroughly so that the strong northeast winds that occurred on the 21st whipped up great quantities of dust from the wheat country and the semiarid parts of the interior and carried westward and southward as a dust cloud of great magnitude that subsequently blew itself out over the Pacific Ocean. The strength of the wind was such as to overcome and blow down frail structures and even great trees. So high winds were quite exceptional for the time and place. Forest and brush fires broke out suddenly over much of the territory invaded by the dust storm; the very low relative humidity and poor visibility made fire suppression very difficult.

The winds subsided during the night of the 22d and 23d and during the daylight hours of the 23d but a smoke pall continued for several days in the territory affected.

The strong northeast winds were due to the presence of a large mass of cool dense air centered over the northern part of the Province of Alberta and especially to the relative position of this cool air mass with respect to one of higher temperature and less density than occupied the northern border States of Idaho, Montana, and the Great Basin. The isobaric chart, Figure 1 shows an isobar of 30.7 inches open to the northward, thus marking the

[1] Somewhat condensed from the original.—ED.

southward extension of the denser air and as shown by the wind arrows an air movement toward the less dense air mass over the Great Basin has already set in. Normally there is a flow of air from regions of great air density to regions of less density. Figure 2 shows the isobaric situation 12 hours later than Figure 1 and it also

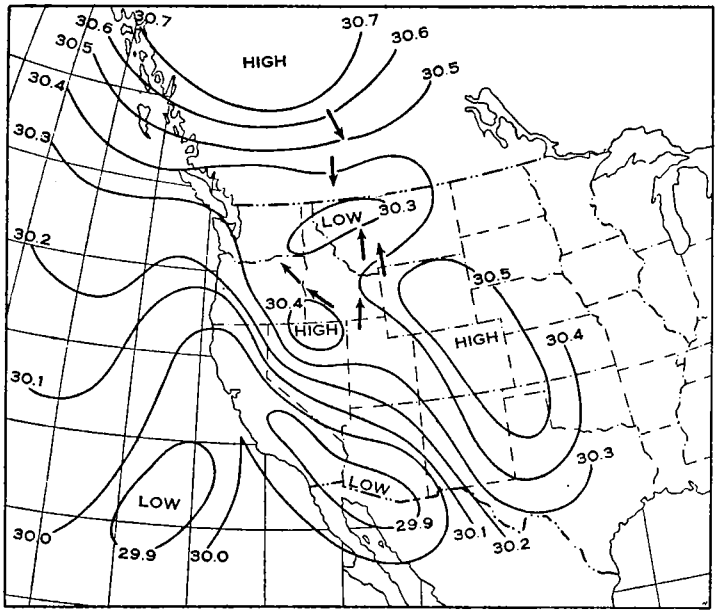

FIGURE 1.—Isobaric chart 5 a. m. 120th meridian time April 21, 1931

shows by the shaded area over Washington that the dust storm had already taken tangible form; the subsequent charts portray the regions of great dust intensity by solid shading.

The strength of the northeast winds during the 21st was augmented by a very pronounced fall in atmospheric

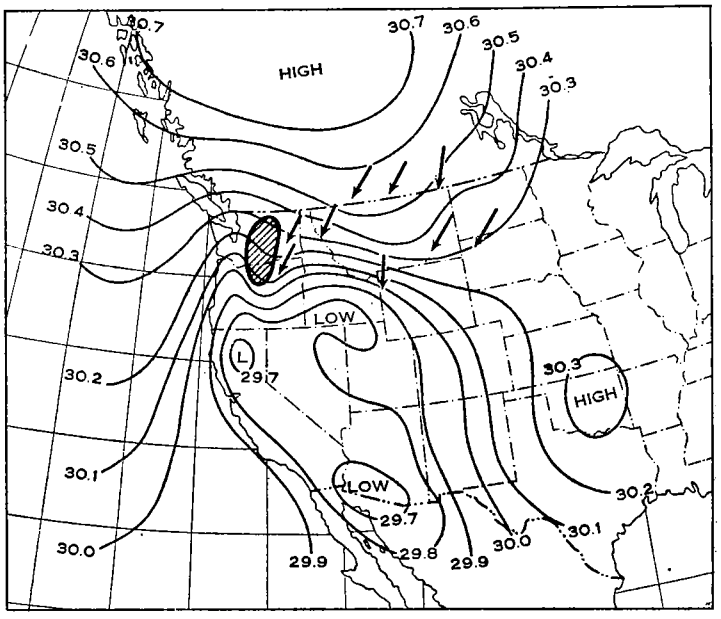

FIGURE 2.—Isobaric chart 5 p. m. 120th meridian time April 21, 1931. Shaded area shows position of duststorm and arrows wind direction

pressure over southwestern United States and up to Oregon and southern Idaho best shown by Figure 3 on which the difference in pressure between the cool, dense air in the northeast and the less dense over the Great Basin is 1.35 inches. This great difference in pressure supplied the energy of the northeast winds as manifested in the destruction of frail structures, the blowing down of great trees and uprooting of others as shown on the inset sheet. (Fig. 6.)

The next chart of the series, Figure 4, marks the end of the dust storm. The pressure level in the cool dense

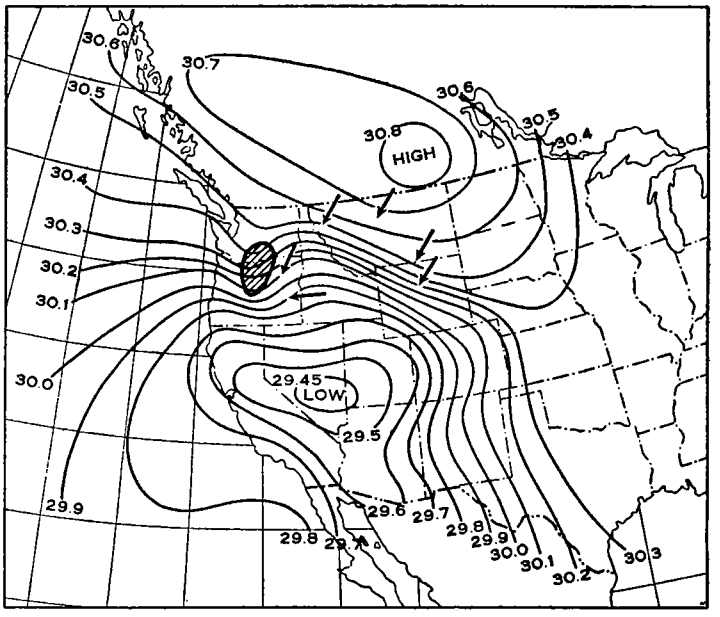

FIGURE 3.—Isobaric chart 5 a. m. 120th meridian time April 22, 1931. Wind direction by arrows and position of dust storm in solid shading

area has fallen four tenths of an inch and the pressure situation has drifted so far to the east and south as to no longer control the wind circulation in Washington and Oregon.

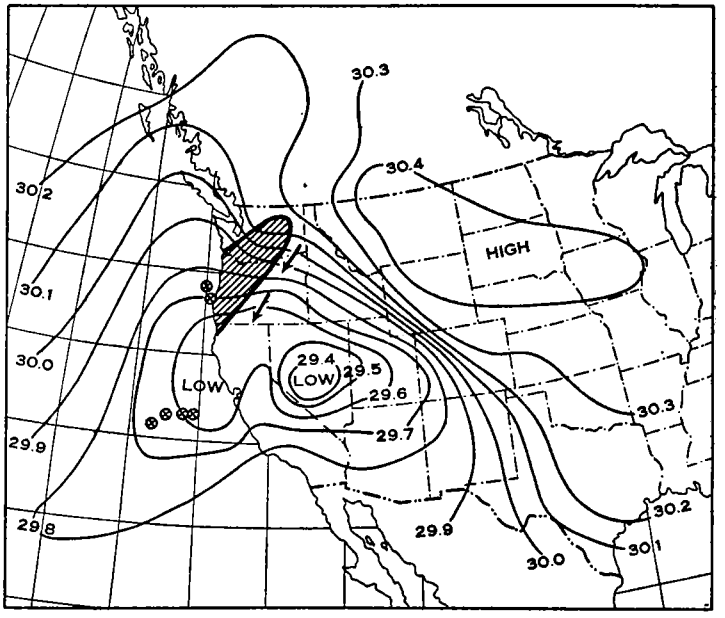

FIGURE 4.—Isobaric chart 5 a. m. 120th meridian time April 23, 1931. Crosses show approximate positions of vessels that observed dust storm; solid shading, position of dust storm: wind directions by arrows

The progress of the great dust front is graphically shown in Figure 5 based upon reports from airway and other stations.

The arrival overhead of the colder air at Pasco, Wash., was heralded by increasing cloudiness and light drizzling rain. At 2 p. m. Pasco's wind had become southeast, 15 m. p. h. but at Arlington in the northwestern part of the State the wind increased to *northeast strong* from *east*

light and "sand storm" was reported.[2] At Umatilla on the Columbia River about 200 miles southeast of Arlington dust clouds were observed to the westward. Grand Dallas near to Dalles and close to the eastern entrance to the Columbia River Gorge reported dust clouds visible to the east. During this period (p. m. of 21st) the barometer was rising at Spokane, Pasco, and Walla Walla, clearly indicating the approach overhead of colder air; at the same time, however, an unusual fall in the barometer was taking place at Burns, Oreg., and Boise, Idaho (0.20 inch in 3 hours), thus tending to greatly increase the strength of the northeast winds.

The advancing northeast wind was a deep one, as evidenced by the pilot-balloon run at Spokane, Wash., at 3 p. m. when northeast gales were observed to the top of the run at about 5,000 feet; the great height was also evidenced by the experience of a Varney mail plane which left Pasco about 1 p. m. of the 22d climbed to the level of 14,500 feet in an effort to surmount the dust cloud. The pilot lost sight of the ground below and when he recovered his bearings the waters of the Pacific came into view near Seaside, Oreg., about 60 miles west of Portland. The strength of the tail wind had been underestimated by the pilot and his plane passed its destination.

The free-air winds above Paso, 3 p. m. of the 22d, were as follows:

At 700 feet 40 m. p. h.
At 1,400 feet 77 m. p. h.
At 2,000 feet 78 m. p. h.
At 2,600 feet 71 m. p. h.

Space does not permit the recital of the items of interest that were reported during the passage of the dust cloud from Tacoma on the north to Mount Shasta on the South. The continuation of the storm over the Pacific is described in the following.

THE DUST STORM CONTINUES OVER THE PACIFIC [3]

Five vessels navigating the Pacific near the west coast of the United States encountered the dust storm hereinbefore described on April 22, 23, and 24. The vessels have been listed and the remarks in reference to the storm are given in tabulated form following.

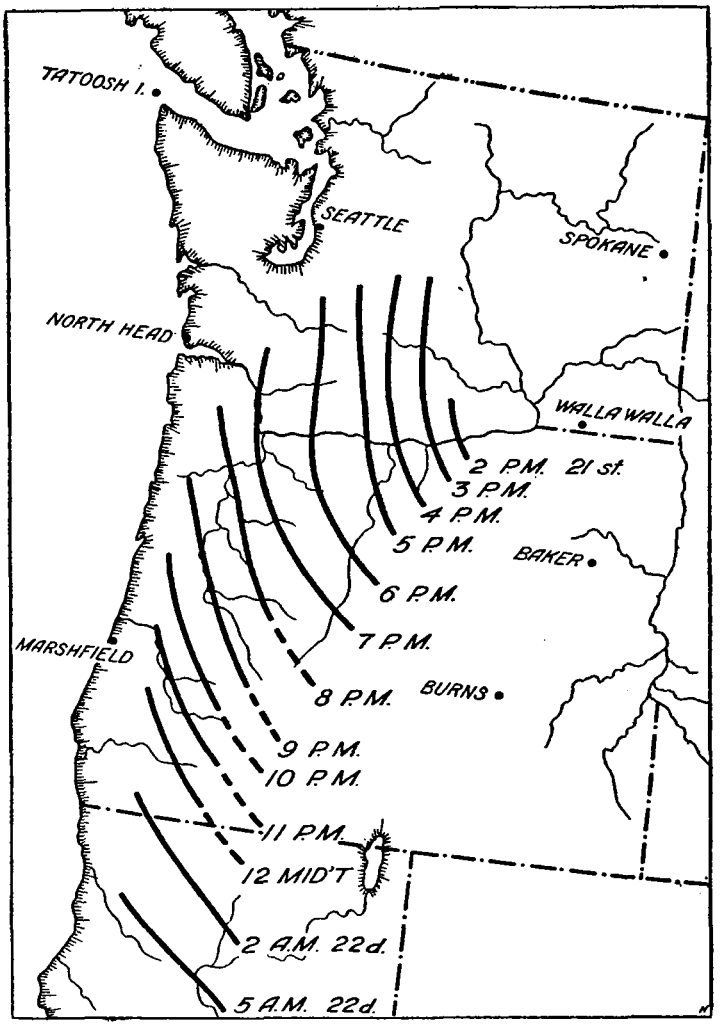

FIGURE 5.—Dust-storm fronts, hourly, as it passed over Washington, Oregon, and California

[2] Cf. Brooks, Chas. F. Warm, dry gale and dust storm in Northwest. Bulletin American Meteorological Society 12:112-13.
[3] Condensed from reports received by the Marine Division, U. S. Weather Bureau.

Vessels encountering dust storm in east Pacific

Name	Latitude	Longitude	Date and time	Wind direction and force	Remarks
	° ′	° ′			
Albertolite	44 06 N	125 00 W	22d	NE. 6	Visibility so low it necessitated navigating as in fog. At this time the atmosphere was filled with fine particles of dust or sand and there was a distinct odor of smoke.
Emma Alexander	43 31 N	124 46 W	22d	NE. 6	Ship ran into a heavy dust storm—dust covering entire ship and shutting off visibility to the extent that it was necessary to sound the whistle.
Mericos H. Whittier	36 45 N	125 47 W	22d	NW. 6	When first encountered it was considered a low fog bank; visibility was restricted to about 3 miles and the sky was perfectly clear. But when daylight arrived it was noticed that the ship had a coating of fine brown-colored dust all over. During the 23d the dust bank remained at practically the same consistency throughout the day having an altitude of about 30° but from 5 p. m. it was noticed to be getting thicker and visibility decreased to about 1½ miles. During the early morning of the 24th the wind backed to SSW. 2 the dust gradually thinning until at 8 a. m. the atmosphere was quite clear except for the haze caused by falling rain. The ship's position at this time was lat. 34° 30′ N., long. 131° 45′ W.
Somme	36 34 N	127 30 W	23d	W. 2	Found heavy coat of fine brown dust that looked like volcanic ash.
Maui	36 20 N	127 19 W	23d	NNW. 3	Apr. 23 at 5 a. m. lat. 36° 20′ N.; long. 127° 19′ W. until 9 p. m. same date in lat. 34° 40′ N.; long. 131° 37′ W. this vessel was in a heavy dust area, wind NNW. to N. Area extended over 240 miles in SW.-NE. direction.

(To face p. 197)

FIGURE 6.—Wind destruction: Upper shows abandoned orchard trees uprooted by the northeast gales; lower, a mountain home and outbuilding crushed by heavy timber (near base of Mount Hood)